Efficiency Improvement of Mobile Antenna by Controlling Ground Structure

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Abstract - The proposed antenna structure with modified ground plane that fully covers Bluetooth and Wireless Fidelity (Wi-Fi) applications. In order to enhance the efficiency, a resonator which consists of a closed loop of a ground plane and lumped inductor (L) are proposed. The closed loop is connected to the ground plane with open-end extension by lumped inductor for easy control. This antenna designed on Flame Retardant Type 4 (FR-4) with 1 mm-thickness was used as the substrate (ε_r= 4.4, tan δ = 0.02). The overall volume of Printed Circuit Board (PCB) is 40 × 20 ×1 mm^3 and the size of a closed loop is 10mm ×20mm. A -6 dB bandwidth covering 250 MHz (2.38 GHz−2.62 GHz) is achieved and average efficiency of 69.05% is obtained in measurement. This technique is versatile and improves the antenna performances.

Index Terms — **PIFA, Mobile device, Efficiency.**

1. Introduction

The Planar Inverted–F Antenna (PIFA) is currently the most popular for mobile devices because it has many advantages such as low profile, compact size and easy processing. In recent years, many researches have focused on miniaturization of the antennas for wireless communications. Mobile antennas are designed for compact size, wide bandwidth and high efficiency. It is important to be able to accurately quantify each of these parameters, which is relatively easy for the size and bandwidth but is difficult for the antenna efficiency[1].

As more features have been added to new generation of wireless communication, the size of mobile devices has become progressively smaller. While this trend of size reduction, as demanded by the consumers, was made possible by advancements in battery technology, Liquid Crystal Display (LCD) and low-power/high integrated circuit technology, the antenna is not as prone to size reduction since their performance is related to the occupied volume [2−3]. Modern mobile devices are extraordinary complex systems and structure from an Elctromagnetics (EM) point of view, because of the presence of the battery, display, keypad and various other components.The dimension for antenna isphysically limited and enhancement of the small antenna efficiency is difficult since radiation performance of the mobile antenna is closely related to its physical volume [2−3]. An obvious way to enhance the performance is to increase the antenna size. However, the area allocated for the antenna is limited andit is a challange for antenna engineers to achieve good performances in a limited given space.

The ground plane is known as a good radiator[4] and the performance of a PIFA depends on the size of the ground plane [5].In order to determine the appropriate antenna to use, it is necessary to evaluate the electrical characteristics and how the antenna can be situated with respect to the overall wireless communication system[6].The proposed ground structure is realized by simply adding a closed loop in the ground plane of the conventional PIFA and lumped inductor can be used to connect the ground plane for open-end extension with the closed loop.

Efficiency improvement of mobile antenna has been verified through numerical simulations and experimental results. Presented data is useful in the design of PIFA for applications requiring high efficiency in a small ground plane. Measurement data was obtained using Agilent E5071Cnetwork analyzer and three dimensional anechoic chamber.

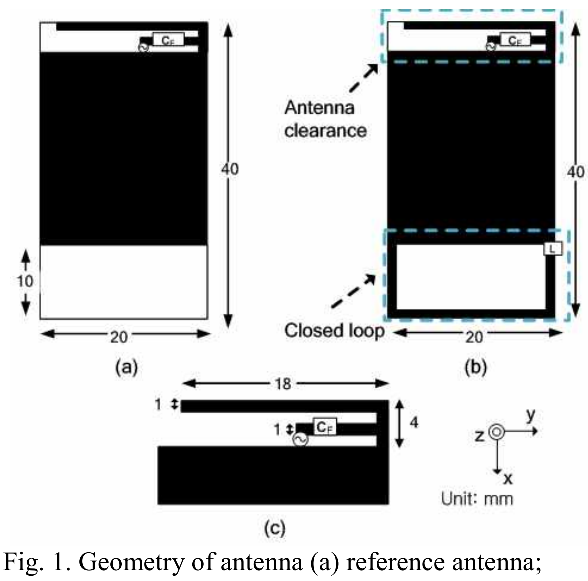

Fig. 1. Geometry of antenna (a) reference antenna; (b) antenna with proposed ground structure; (c) antenna elements

2. Antenna Designs and Analysis

The geometry of the antenna of proposed ground structure with the antenna clearance of 20 mm × 4 mm is shown in Fig. 1(b). It is installed at bottom end of the long side of ground plane and connected by lumped inductor. The value of $C_F$is 0.4 pF. The proposed antenna structure consists of a feed structure, antenna elements, a ground plane and a closed loop with lumped inductor. Fig 2 shows the effects of the variation of L on radiation efficiency. The values of L are used to measure the characteristics of the antenna are 10–70 nH with the steps of 10 nH. It can be observed that the maximum efficiency is obtained when L is 40 nH. Fig. 3 shows the simulated and measured return loss characteristics. The simulated and measured results resemble each other. Fig. 4 compares the realized efficiency of the modified ground structure with L=40 nH and reference antenna.

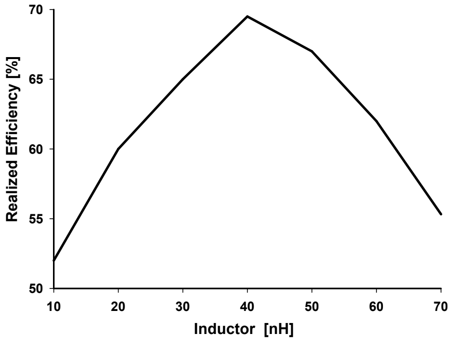

Fig.2. Realized efficiency with L variation at 2.45GHz

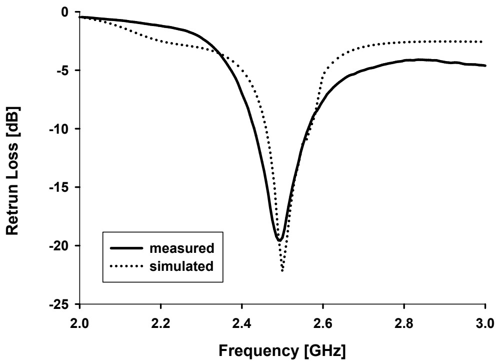

Fig. 3. Simulated and measured return loss

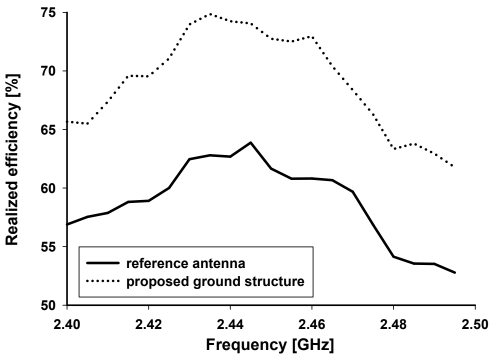

Fig.4 .Realized efficiency of reference and proposed ground structure

3. Experimental Results and Discussion

Experiments show the significant influences of a closed loop with L variation on the realized efficiency. The effects of the ground plane on radiation efficiency are studied using the open-end extension. The reference and proposed ground structure were successfully simulated and measured. The realized efficiency of the proposed ground structure can be easily controlled by simply adjusting the lumped inductor in the closed loop. Fig. 3 shows simulation results with impedance bandwidth of 180 MHz (2.42 GHz−2.6 GHz) and measured results with impedance bandwidth of 250 MHz (2.38 GHz–2.63 GHz) under Voltage Standing Wave Ratio (VSWR) = 3:1. The realized efficiency of the proposed ground structure ranges from 61.7% to 74.8% and average realized efficiency is 69.05% indicating good radiation performance. However, realized efficiency of reference antenna ranges from 52.8% to 63.9% and average realized efficiency is only 58.8% in the range of 2.4GHz to 2.5GHz.

4. Conclusion

The proposed ground structure for PIFA was designed and analyzed for Bluetooth and Wi-Fi applications in mobile devices. In addition, the proposed ground structure can be easily fabricated because it used only a closed loop with lumped inductor. It is connected to the ground plane by lumped inductor for ground mode control and compact design for practical applications. The characteristics of the closed loop have proven to be important for the antenna performances. As a result, high realized efficiency has been achieved in measurement. This technique can be applied at different frequencies and with different ground planes. The proposed ground structure for mobile devices is competitive for practical applications and significantly improves realized efficiency by using the ground structure. This antenna configuration is expected to be fully utilized in modern mobile devices.

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References

[1] Ronald H Johnston and John, "An Improved Small Antenna Radiation-Efficiency Measurement Method," *IEEE Antennas Propagat.*, Vol.40, No.5, Oct. 1988.
[2] B.S Yarman, *Design of Ultra Wideband Antenna Matching Networks,* Springer, New York, 2008, pp.39-43.
[3] M.C Huynh and W.L. Stutzman, "Ground plane effects on Planar inverted-F antenna (PIFA) performance," *IEEProc.-Microw.. Antennas Propagt.,* Vol. 150, No.4, pp.209-213, Aug. 2003.
[4] R.F. Harrington and J.R. Mautz, "theory of Characteristic Modes for Conducting Bodies," *IEEETrans. Antennas Propagt.,* Vol.19, No.5, pp. 622-628,Sep.1971.
[5] R.F. Harrington, 'Effect of antenna size on gain, bandwidth and efficiency,'*Journal of Research of the National Bureau of standards-D. Radio Propagat.,* 64D, pp. l-12, Jun. 1960
[6] Kathleen L. Virga, Yahya Rahmat-Samii, "Low-Profile Enhanced-Bandwidth PIFA Antennas for Wireless Communications Packaging," *IEEETrans. Microwave theory and techniques,* Vol. 45, No. 10, pp.1879-1888, Oct. 1997.